

## 99-E-334, Spallation Neutron Source, Oak Ridge National Laboratory, Oak Ridge, Tennessee

(Changes from FY 2005 Congressional Budget Request are denoted with a vertical line in the left margin.)

### 1. Construction Schedule History

	Fiscal Quarter				Total Estimated Cost (\$000)	Total Project Cost (\$000)
	A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
FY 1999 Budget Request ( <i>Preliminary Estimate</i> ) .....	1Q 1999	4Q 2003	3Q 2000	4Q 2005	1,138,800	1,332,800
FY 2000 Budget Request .....	1Q 1999	4Q 2003	3Q 2000	1Q 2006	1,159,500	1,360,000
FY 2001 Budget Request .....	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,220,000	1,440,000
FY 2001 Amended Budget Request ( <i>Performance Baseline</i> ) .....	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700
FY 2006 Budget Request .....	1Q 1999	4Q 2003	1Q 2000	3Q 2006	1,192,700	1,411,700

## 2. Financial Schedule <sup>a</sup>

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
1999	101,400	101,400	37,140
2000	100,000	100,000	105,542
2001	258,929	258,929	170,454
2002	276,300	276,300	253,059
2003	210,571	210,571	276,887
2004	123,865 <sup>b</sup>	123,865 <sup>b</sup>	205,884
2005	79,891 <sup>bc</sup>	79,891 <sup>bc</sup>	96,090
2006	41,744 <sup>c</sup>	41,744 <sup>c</sup>	47,644

## 3. Project Description, Justification and Scope <sup>d</sup>

The purpose of the Spallation Neutron Source (SNS) Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering and related research in broad areas of the physical, chemical, materials, and biological sciences. The SNS will be a national facility with an open user policy

<sup>a</sup> Beyond the 5 instruments included in the SNS line item project, a broad instrument development program is being executed over the next several years to qualify and provide instruments for the remaining 19 neutron beam lines (the target station is designed to accommodate a total of 24 instruments). Instrument proposals undergo a scientific peer review process to evaluate technical merit; those concepts that are accepted may then establish interface agreements with the SNS Project. Expected funding sources include appropriated funds through the Department of Energy and other Federal agencies, private industry, and foreign entities. These instruments will all be delivered after completion of the SNS line item project. The instruments listed below have been initiated with the identified funding sources. As indicated, five of these instruments have been grouped together for the sake of management efficiency to form the “SNS Instruments – Next Generation” (SING) project, which is budgeted in the Basic Energy Sciences program as a Major Item of Equipment.

1. Cold Neutron Chopper Spectrometer – Basic Energy Sciences grant to Pennsylvania State University;
2. Wide Angle Chopper Spectrometer – Basic Energy Sciences grant to California Institute of Technology;
3. High Pressure Diffractometer – Basic Energy Sciences (SING);
4. High Resolution Chopper Spectrometer – Basic Energy Sciences (SING);
5. Single Crystal Diffractometer – Basic Energy Sciences (SING);
6. Hybrid Spectrometer – Basic Energy Sciences (SING);
7. Disordered Materials Diffractometer – Basic Energy Sciences (SING);
8. Fundamental Physics Beam Line – Nuclear Physics;
9. Engineering Diffractometer – the Canada Foundation for Innovation (CFI); and
10. Neutron Spin Echo – Forschungszentrum Julich GmbH (FZJ).

The final 9 SNS instruments will be selected under this process and identified when they are approved and funded.

<sup>b</sup> Construction funding was reduced by \$735,000 as a result of the FY 2004 rescission. The reduction is restored in FY 2005 to maintain the TEC and project scope.

<sup>c</sup> Construction funding was reduced by \$644,000 as a result of the FY 2005 rescission. The reduction is restored in FY 2006 to maintain the TEC and project scope.

<sup>d</sup> As part of the development of Oak Ridge National Laboratory, other buildings may be located on Chestnut Ridge, which is the site of the SNS and is located just across Bethel Valley Road from improvements planned for the main ORNL campus. For example, the Center for Nanophase Materials Sciences (CNMS) is being built on Chestnut Ridge, because research activities at the CNMS will integrate nanoscale science research with: neutron science; synthesis; and theory, modeling, and simulation. The CNMS is adjacent to the SNS Laboratory – Office Building and is connected to it by a walkway. See construction project datasheet 03-R-312 for further information on the CNMS.

attractive to scientists from universities, industries, and federal laboratories. It is anticipated that the facility, when fully operating, will be used by 1,000-2,000 scientists and engineers each year and that it will meet the national need for neutron science capabilities well into the 21<sup>st</sup> Century.

The scientific justification and need for a new neutron source and instrumentation in the U.S. were established by numerous studies by the scientific community since the 1970s. These include the 1984 National Research Council study *Major Facilities for Materials Research and Related Disciplines* (the Seitz-Eastman Report), which recommended the immediate start of the design of both a steady-state source and an accelerator-based pulsed spallation source. More recently, the 1993 DOE Basic Energy Sciences Advisory Committee (BESAC) report *Neutron Sources for America's Future* (the Kohn Panel Report) again included construction of a new pulsed spallation source with SNS capabilities among its highest priorities. This conclusion was even more strongly reaffirmed by the 1996 BESAC Report (the Russell Panel Report), which recommended the construction of a 1 megawatt (MW) spallation source that could be upgraded to significantly higher powers in the future.

Neutron scattering enables the determination of the positions and motions of atoms in materials, and it has become an increasingly indispensable scientific tool. Over the past decade, it has made invaluable contributions to the understanding and development of many classes of new materials, from high temperature superconductors to fullerenes, a new form of carbon. The information that neutron scattering provides has wide impacts. For example, chemical companies use neutrons to make better fibers, plastics, and catalysts; drug companies use neutrons to design drugs with higher potency and fewer side effects; and automobile manufacturers use the penetrating power of neutrons to understand how to cast and forge gears and brake discs in order to make cars run better and more safely. Furthermore, research on magnetism using neutrons has led to higher strength magnets for more efficient electric generators and motors and to better magnetic materials for magnetic recording tapes and computer hard drives.

Based on the recommendations of the scientific community obtained via the Russell Panel Report, the SNS is required to operate at an average power on target of at least 1 megawatt (MW); although the designers had aimed for 2 MW, current projections fall between 1 to 2 MW. At this power level, the SNS will be the most powerful spallation source in the world-many times that of ISIS at the Rutherford Laboratory in the United Kingdom. Furthermore, the SNS is specifically designed to take advantage of improvements in technology, new technologies, and additional hardware to permit upgrades to substantially higher power as they become available. Thus, the SNS will be the nation's premiere neutron facility for many decades.

The importance of high power – and consequently high neutron intensity – cannot be overstated. The properties of neutrons that make them an ideal probe of matter also require that they be generated with high flux. (Neutrons are particles with the mass of a proton, with a magnetic moment, and with no electrical charge.) Neutrons interact with nuclei and magnetic fields; both interactions are extremely weak, but they are known with great accuracy. Because they have spin, neutrons have a magnetic moment and can be used to study magnetic structure and magnetic properties of materials. Because they weakly interact with materials, neutrons are highly penetrating and can be used to study bulk phase samples, highly complex samples, and samples confined in thick-walled metal containers. Because their interactions are weak and known with great accuracy, neutron scattering is far more easily interpreted than either photon scattering or electron scattering. However, the relatively low flux of existing neutron sources and the small fraction of neutrons that get scattered by most materials, mean that most measurements are limited by the source intensity.

The pursuit of high-flux neutron sources is more than just a desire to perform experiments faster, although that, of course, is an obvious benefit. High flux enables broad classes of experiments that cannot be done with low-flux sources. For example, high neutron intensity enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) pulses to a target/moderator system where neutrons are produced by a nuclear reaction process called spallation. The process of neutron production in the SNS consists of the following: negatively charged hydrogen ions are produced in an ion source and are accelerated to approximately 1 billion electron volts energy in a linear accelerator (linac); the hydrogen ion beam is injected into an accumulator ring through a stripper foil, which strips the electrons off of the hydrogen ions to produce a proton beam; the proton beam is collected and bunched into short pulses in the accumulator ring; and, finally, the proton beam is injected into a heavy metal target at a frequency of up to 60 Hz. The intense proton bursts striking the target produce pulsed neutron beams by the spallation process. The high-energy neutrons so produced are moderated (i.e., slowed down) to reduce their energies, typically by using thermal or cold moderators. The moderated neutron beams are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations.

The primary objectives in the design of the site and buildings for the SNS are to provide optimal facilities for the DOE and the scientific community for neutron scattering well into the 21<sup>st</sup> Century and to address the mix of needs associated with the user community, the operations staff, security, and safety.

A research and development (R&D) program is required to ensure technical feasibility and to determine physics design of accelerator and target systems that will meet performance requirements.

The objectives stated above will be met by the technical components described earlier (ion source; linac; accumulator ring; target station with moderators; beam transport systems; and initial experimental equipment necessary to place the SNS in operation) and attendant conventional facilities. As the project design and construction progresses, value engineering analyses and R&D define changes that are applied to the technical baseline to maximize the initial scientific capability of the SNS within the currently established cost and schedule. The SNS project will be considered complete when all capital facilities necessary to achieve the initial baseline goals have been installed and certified to operate safely and properly. In addition, to the extent possible within the Total Project Cost, provisions will be made to facilitate a progression of future improvements and upgrades aimed at keeping SNS at the forefront of neutron scattering science throughout its operating lifetime. Indeed, the current design contains a number of enhancements (e.g. superconducting radiofrequency (RF) acceleration, best-in-class instruments, more instrument stations, and higher energy ring) that provide higher performance than the conceptual design that was the basis of initial project approval.

The scientific user community has advised the DOE Office of Basic Energy Sciences that the SNS should keep pace with developments in scientific instruments. Since the average cost for a state-of-the-art instrument has roughly doubled in recent years, SNS reduced the number of instruments provided within the project TEC. Although this translated into an initial suite of five rather than the ten instruments originally envisioned, the cumulative scientific capability of the SNS has actually increased more than ten-fold. In order to optimize the overall project installation sequence and early experimental operations, three of these instruments will be installed as part of the project; procurement of components for the other two will be completed, with installation occurring during initial low power operations following project completion. As with all scientific user facilities such as SNS, additional and even more capable instruments will be installed over the course of its operating lifetime.

Funds appropriated in FY 2004 were used to continue instrument R&D, design, and procurement. The drift tube linac and coupled cavity linac subsystems were installed and commissioning activities were continued in the linac. Cryogenic refrigerator installation and system cool down were completed, and cryogenic transfer line installation and testing were completed. Cryogenic module fabrication and installation were continued. Ring fabrication and assembly activities were continued. Target fabrication and assembly activities were continued. Most buildings were completed with the exception of ongoing construction work in the target building and the central laboratory and office building.

FY 2005 budget authority will be used to continue R&D, procurement, and installation of equipment for instrument systems. Commissioning of Linac systems will be completed. Installation of accumulator ring and high-energy beam transport systems will continue. Installation and testing of target systems will be performed along with starting preparations for the target systems readiness review. The remaining major construction contracts will be completed. Procurement, installation, and testing will continue for integrated control systems.

FY 2006 budget authority is requested to complete the SNS Project. Procurement and installation of equipment for instrument systems will be performed. Accelerator readiness reviews will be completed, and ring and target systems will be successively commissioned. All requirements to begin operations will be met and all SNS facilities will be turned over to operations.

## 4. Details of Cost Estimate <sup>a</sup>

(dollars in thousands)		
	Current Estimate	Previous Estimate
Design and Management Costs		
Engineering, design and inspection at approximately 20% of construction costs .....	160,500	160,500
Construction management at approximately 2% of construction costs .....	15,900	15,900
Project management at approximately 13% of construction costs.....	104,700	104,700
Total, Design Costs (23.6% of TEC).....	281,100	281,100
Construction Costs		
Improvements to land (grading, paving, landscaping, and sidewalks) .....	31,500	31,500
Buildings .....	250,624	239,800
Utilities (electrical, water, steam, and sewer lines).....	20,900	20,900
Technical Components .....	524,040	520,600
Total, Construction Costs .....	827,064	812,800
Standard Equipment.....	17,500	17,500
Major computer items .....	5,500	5,500
Design and project liaison, testing, checkout and acceptance.....	31,000	31,000
Subtotal .....	1,162,164	1,147,900
Contingencies at approximately 3% of above costs <sup>b</sup> .....	30,536	44,800
Total, Line Item Costs (TEC).....	1,192,700	1,192,700

## 5. Method of Performance

The SNS project is being carried out by a partnership of six DOE national laboratories, led by Oak Ridge National Laboratory, as the prime contractor to DOE. The other five laboratories are Argonne, Brookhaven, Lawrence Berkeley, and Los Alamos National Laboratories and Thomas Jefferson National Accelerator Facility. Each laboratory is assigned responsibility for accomplishing a well defined portion of the project's scope that takes advantage of their technical strengths: Argonne – Instruments; Brookhaven – Accumulator Ring; Lawrence Berkeley – Ion Source; Los Alamos – Normal conducting Linac and RF power systems; TJNAF – Superconducting Linac; Oak Ridge - Target. Project execution is the responsibility of the SNS Associate Laboratory Director with the support of a central SNS Project Office at ORNL, which provides overall project management, systems integration, ES&H, quality assurance, and commissioning support. The SNS Associate Laboratory Director has authority for directing the efforts at all six partner laboratories and exercises financial control over all project activities. ORNL has subcontracted to an Industry Team that consists of an Architect-Engineer for the conventional facilities design and a Construction Manager for construction installation, equipment

<sup>a</sup> The project is using the appropriated funds included in the TEC to meet or exceed the project performance baseline. The project is also accepting transferred surplus materials and equipment to the extent possible. Examples of the transferred items include ring pumps, lead bricks, concrete blocks, trailers and furniture. The net book value of the surplus materials will be far less than one percent of the TEC over the life of the project. All such transferred materials will be appropriately recorded as non-fund cost and capitalized.

<sup>b</sup> The current baselined contingency level, expressed as a percentage of the remaining effort to complete the line item project, is approximately 20%.

procurement, testing and commissioning support. Procurements by all six laboratories are being accomplished, to the extent feasible, by fixed price subcontracts awarded on the basis of competitive bidding.

## 6. Schedule of Project Funding

(dollars in thousands)					
	Prior Year Costs	FY 2004	FY 2005	FY 2006	Total
Project Cost					
Facility Cost <sup>a</sup>					
Line Item TEC .....	843,082	205,884	96,090	47,644	1,192,700
Other project costs					
R&D necessary to complete project <sup>b</sup> .....	81,846	1,188	614	0	83,648
Conceptual design cost <sup>c</sup> .....	14,397	0	0	0	14,397
NEPA Documentation costs <sup>d</sup> .....	1,928	0	0	0	1,928
Other project-related costs <sup>e</sup> .....	32,201	17,951	36,847	30,925	117,924
Capital equipment not related construction <sup>f</sup> .....	911	130	62	0	1,103
Total, Other project costs .....	131,283	19,269	37,523	30,925	219,000
Total project cost (TPC) .....	974,365	225,153	133,613	78,569	1,411,700

## 7. Related Annual Funding Requirements

(FY 2007 dollars in thousands)		
	Current Estimate	Previous Estimate
Facility operating costs .....	45,700	45,700
Facility maintenance and repair costs .....	24,800	24,800
Programmatic operating expenses directly related to the facility .....	47,700	47,700
Capital equipment not related to construction but related to the programmatic effort in the facility .....	14,100	14,100
GPP or other construction related to the programmatic effort in the facility .....	1,000	1,000
Utility costs .....	19,400	19,400
Accelerator Improvement Modifications (AIMs) .....	7,300	7,300
Total related annual funding (4Q FY 2006 will begin operations) .....	160,000	160,000

<sup>a</sup> Construction line item costs included in this budget request are for providing Title I and II design, inspection, procurement, and construction of the SNS facility for an estimated cost of \$1,192,700,000.

<sup>b</sup> A research and development program at an estimated cost of \$83,648,000 is needed to confirm several design bases related primarily to the accelerator systems, the target systems, safety analyses, cold moderator designs, and neutron guides, beam tubes, and instruments. Several of these development tasks require long time durations and the timely coupling of development results into the design is a major factor in detailed task planning.

<sup>c</sup> Costs of \$14,397,000 are included for conceptual design and for preparation of the conceptual design documentation prior to the start of Title I design in FY 1999.

<sup>d</sup> Costs of \$1,928,000 are included for completion of the Environmental Impact Statement.

<sup>e</sup> Estimated costs of \$117,924,000 are included to cover pre-operations costs.

<sup>f</sup> Estimated costs of \$1,103,000 to provide test facilities and other capital equipment to support the R&D program.

During conceptual design of the SNS project, the annual funding requirements were initially estimated based on the cost of operating similar facilities (e.g., ISIS and the Advanced Photon Source) at \$106,700,000. The operating parameters, technical capabilities, and science program are now better defined and the key members of the ORNL team that will operate SNS are now in place. Based on these factors, the SNS Project developed a new estimate of annual operating costs, which was independently reviewed by the Department, and provides the basis of the current estimate indicated above. FY 2007 will be the first full year of operations and this estimate is generally representative of the early period of SNS operations. If proposed upgrades and instrumentation plans are carried out in the future, the annual funding requirements will increase by an additional 10-15 percent.